Multilevel Spine Injuries: A 15-Year Institutional Experience

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Abstract

Objective: To highlight clinical features, therapeutic approaches and functional outcomes.

Methods: Patients with congenital, metabolic, rheumatologic diseases and neoplasms were excluded. Each level of vertebral injury was designated as primary, secondary or tertiary. The pattern of these injuries was plotted and compared with that in Jefferson's series. Neurological functions were evaluated according to the American Spinal Injury Association (ASIA). Modified Prolo Economic Functional Rating Scale was used to assess the functional outcome. All of the statistical calculations were performed using the Statistical Package for Social Sciences and p<0.05 was considered statistically significant.

Results: Altogether, out of 125 patients (11.45%) studied, a total of 513 injured vertebrae were diagnosed (mean, 4.10, range, 2-18 vertebrae). Seventy-two (57.6%) were at contiguous levels and 53 (42.4%) at noncontiguous levels. There were 93 males and 32 females with mean age of 34.57 years (range, 11 months-70 years). The mean follow-up time was 49 months. The frequent cause of injury was motor vehicle collision (48.6%). Forty-four patients were treated conservatively and 81 surgically.

Conclusion: Thorough clinical examination and fuller spinal column imaging evaluation are key guides to rule out a secondary or tertiary vertebra fracture and/or dislocation in vertebral injury associated with high-energy trauma. Life support principles guide initial management and all unstable levels must be fixed.
Keywords: Multilevel; Spine Injuries; Contiguous; Noncontiguous; High-energy trauma

Introduction

Injuries to the vertebral column at more than one level are not uncommon [1, 2]. They have been recognized for a long time [3, 4, and 5]. They occur as a result of high-velocity trauma, in which the dissipation of high forces leads to multilevel involvement [6]. Often, the second or third levels of injury are not recognized early enough to prevent clinically significant extension of the neurologic deficit, pain pattern, spinal instability and/or deformity [7]. Although many studies discuss the evaluation and management of vertebral fractures and/or dislocations involving one segment of the spine, only a few reports comment on the incidence of multilevel involvement [8]. The reported incidence in the literature ranges from 4.2% to 9.7% [1, 9]. Therefore, studying multilevel spine injuries seemed needed. To our knowledge, we report the largest series of 125 patients with multilevel spine injuries among 1092 spinal trauma (incidence of 11.45%) over a period of 15 years. The purpose of this study was to highlight clinical features, therapeutic approaches and functional outcomes of multilevel spine injuries.

Materials and methods

The medical files of all patients with spinal injuries treated in the orthopedics and Trauma Surgery Department from 15 March 2003 to 15 March 2018 were retrospectively reviewed. Of the 1092 patients with acute spinal injury admitted, 125 (11.45%) were found to have multilevel spine injuries. These injuries were classified as "contiguous" when more than one adjacent vertebra was involved, and as "noncontiguous" if there is at least a normal spinal segment between the lesions of the same structural type as the injured segments.

For the purpose of this study each level of vertebral injury was designated as primary, secondary or tertiary. The primary lesion was the vertebral fracture and/or dislocation first identified which initially was considered to account for the patient’s symptoms or neurological signs on admission and appeared most unstable on the standard radiographs and Computed Tomography (CT) scans. The secondary lesion was vertebral injury unrecognized initially, or which when diagnosed simultaneously was felt to have less neurologic significance than the primary lesion and was stable by radiographic criteria. When three levels of injury existed, the secondary lesion was the one with greater actual or potential neurologic significance than the tertiary vertebral injury. The pattern of these injuries, both primary and secondary, was plotted and compared with that in Jefferson's series [5].

All patients with multilevel spinal fractures and/or dislocations regardless of their neurological status were included in the study. Patients presenting minor injuries such as isolated spinous process fractures (Clay-Shoveler's syndrome), minor spinal sprains were excluded. Patients with congenital, metabolic, rheumatologic diseases and neoplasms such as Klippel-Feil syndrome, osteoporosis, ankylosing spondylitis, and multiple myeloma were excluded. Fractures involving the occipital cervical junction and sacrum were also excluded since they have a unique anatomy, biomechanics, and classification.

There were 93 males and 32 females with mean age of 34.57 years and mean follow-up time of 49 months. Forty-four patients were treated conservatively and 81 surgically. The overall mortality rate was 12.8%.

In all patients, we evaluated neurological function according to the American Spinal Injury Association (ASIA). Modified Prolo Economic Functional Rating Scale [10] was used to assess the functional outcome with normal function (excellent): 9+10, grade 1 (good): 7+8, grade 2 (fair): 5+6, grade 3 (poor): 2-4. Diagnostic imaging studies, including conventional cervical, thoracic and lumbar radiographs were obtained in all patients. If the presence of a fracture and/or dislocation was uncertain CT scans were required (115 patients: 92%) or if a patient had a spinal cord injury (SCI), magnetic resonance imaging (MRI) was obtained (26 patients: 20.8%). All of the statistical calculations were performed using the Statistical Package for Social Sciences for macOS (SPSS version 24.0), p<0.05 was considered statistically significant.

Results

Altogether, out of 125 patients (11.45%) studied, a total of 513 injured vertebrae were diagnosed (mean, 4.10, range, 2-18 vertebrae). The region involved was from C1 to L5. There were 93 males and 32 females. The age range was 11 months-70 years (mean 34.57). Seventy-six patients (60,
were aged between 18-39 years (young adults). The mean duration of hospital stay was 14 days (range 2-116 days). The causes of injury were motor vehicle collision (MVC, 48.6%), fall-related injuries (40.2%), motor vehicle versus pedestrian accidents (8%), sports-related activities (1.6%) and railway accidents (1.6%). Of the 63 cases involving MVC, 77% were unrestrained at the time of the accident (49 patients). The symptoms and signs included local symptoms, such as cervical or back pain and restriction of motion, and neurological deficits from radiculopathies to tetraplegia.

On admission, 49 patients (39.2%) were neurologically intact (ASIA grade E), 27 patients (21.6%) had incomplete neurological injuries, and 40 (32%) had a complete SCI (ASIA grade A). Neurological status according to the ASIA classification could not be evaluated in 9 patients (7.2%) with severe head injury. At final follow-up, 71 patients (56.8%) were ASIA grade E; 29 patients (23.2%) had full neurological recovery. Five patients (4%) had partial neurological recovery. Only 8 patients (6.4%) who were ASIA grade A on admission remained stationary. However, 2 patients (1.6%) deteriorated their neurological function and passed from ASIA grade E to grade A. Sixteen patients (12.8%) died. ASIA grade A patients (14 patients) accounted for 87.5% of deaths. All patients with SCI were transferred to a rehabilitation center.

Forty-nine patients had associated extraspinal injuries, including head and facial trauma (18.36%), multisystem trauma (24.48%), and orthopedic injuries (57.16%). Among orthopedic injuries; the calcaneal fractures alone accounted for 22.45%; followed by fracture of the distal radius (14.29%). Patients with thoracic and lumbar fractures had more associated injuries compared with those having cervical fractures (p<0.001). Age, gender, and type of neurological deficit were not significantly related to the occurrence of associated injuries (p>0.05). However, the cause of injury was responsible of associated extraspinal injuries (p<0.001).

Of the 125 patients presenting multilevel spinal injuries, 72 (57.6%) were at contiguous levels and 53 (42.4%) at noncontiguous levels in our series. Fifty patients (40%) suffered multilevel spinal fractures and/or dislocations only at cervical levels, 16 patients (12.8%) at cervical and thoracic levels, two patients (1.6%) at cervical and lumbar levels, 12 patients (9.6%) in the thoracic region, 21 patients (16.8%) in the thoracic and lumbar region, 18 patients (14.4%) in the lumbar region, and 6 patients (4.8%) in the cervicothoracolumbar region. Distribution of multilevel spine injuries according to the involved levels is summarized in (Table 1).

The distribution of the primary fractures and/or dislocations mirrored Jefferson's curve quite well, with two major peaks; one at the lower cervical level and the other at thoracolumbar level the spinal level of secondary fractures

### Table 1: Distribution of 125 patients with multilevel spine injuries according to involved level.

<table>
<thead>
<tr>
<th>Level of injury</th>
<th>Number of Contiguous spine injuries (%)</th>
<th>Number of Noncontiguous spine injuries (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical</td>
<td>34 (27.2%)</td>
<td>16 (12.8%)</td>
<td>50 (40%)</td>
</tr>
<tr>
<td>Cervical+Thoracic</td>
<td>6 (4.8%)</td>
<td>10 (8%)</td>
<td>16 (12.8%)</td>
</tr>
<tr>
<td>Cervical+Lumbar</td>
<td>2 (1.6%)</td>
<td>6 (4.8%)</td>
<td>8 (6.4%)</td>
</tr>
<tr>
<td>Cervical+Thoracic+Lumbar</td>
<td>6 (4.8%)</td>
<td></td>
<td>6 (4.8%)</td>
</tr>
<tr>
<td>Thoracic</td>
<td>8 (6.4%)</td>
<td>4 (3.2%)</td>
<td>12 (9.6%)</td>
</tr>
<tr>
<td>Thoracic+Lumbar</td>
<td>14 (11.2%)</td>
<td>7 (5.6%)</td>
<td>21 (16.8%)</td>
</tr>
<tr>
<td>Lumbar</td>
<td>10 (8%)</td>
<td>8 (6.4%)</td>
<td>18 (14.4%)</td>
</tr>
<tr>
<td>Total</td>
<td>72 (57.6%)</td>
<td>53 (42.4%)</td>
<td>125 (100%)</td>
</tr>
</tbody>
</table>
showed major peaks at upper cervical and cervicothoracic levels and two minor peaks at lower thoracic and mid-lumbar levels (Fig. 1).

Figure 1: Distribution of primary and secondary lesions in 125 patients with multiple spinal fractures and/or dislocations.

Of the secondary lesions, 39.7% occurred above and 60.3% below the primary lesion. In 106 patients, there was no delay in diagnosis of the secondary lesions. However, in 19 patients (15.7%) the diagnosis of secondary or tertiary lesions was delayed of 1-140 days (mean, 5.9 days). The delayed recognition of the secondary lesion was seen in upper cervical spine (7.2%), cervicothoracic junction (3.8%), thoracic spine (2.2%), thoraco-lumbar junction (1.4%) and lumbar spine (0.6%).

Sixty patients (48%) had complications. These are death (12.8%), pressure sores (9.6%), urinary tract and surgical site infection (8.8%), mal union and kyphoscoliosis (4.8%), secondary displacement of fracture fragments (3.2%), nonunion (2.4%), transient neurological deficit deterioration (1.6%). Surgery-related complications were wrong-level surgery (1.2%), threatened aortic injury by pedicle screws during posterior instrumentation of the thoracic spine (1.8%) and hoarseness due to recurrent laryngeal nerve injury (1.8%). Of the 44 patients (35.2%) treated non-surgically, 20 patients (16%) wore a Minerva plaster cast, 17 patients (13.6%) wore a thoracolumbosacral plaster cast, one patient (0.8%) with cervical and thoracolumbar injuries wore both a Minerva plaster cast and a thoracolumbosacral orthosis (TLSO) and 6 patients (4.8%) with bed rest and gradual resumption of activities. The average duration of immobilization was 75 days (range 39-138 days). All patients underwent follow-up evaluation with CT scanning or conventional radiographs. Three (2.4%) of the conservatively treated patients needed surgical intervention in the follow-up period for nonunion (1 patient) and kyphoscoliosis (2 patients).

Eighty-one patients (64.8%) treated surgically had at least one unstable injury with or without SCI. Seventy-five patients (60%) with an unstable injury associated with a second stable spine injury were operated for only the unstable level. Five patients (4%) with unstable both primary and secondary injuries required surgical stabilization of both levels. One patients (0.8%) required surgical intervention at three levels. For 45 patients (36%) operated at the cervical spine; anterior approach was performed in 34 patients (27.2%), posterior approach in 4 (3.2%) and combined both approaches in 1 patient (0.8%). They wore a cervical collar after surgery for 4 weeks. However, six patients (4.8%) with unstable multilevel cervical spine injuries without neurological deficit were treated using a modified external fixator composed of halo ring, Ilizarov apparatus and plaster of Paris replacing the artificial synthetic halo vest (Fig. 2).

Figure 2: Modified external fixator made of halo ring, Ilizarov apparatus and Plaster of Paris.

The posterior approach was performed in all 36 patients (28.8%) operated at thoracic or lumbar levels. However, in one patient with threatened aortic injury by pedicle
screws during posterior fixation of multilevel thoracic spine fracture dislocation, the removal of the conflicting screws was done posteriorly after a visual control of the absence of adventitious break-in by a thoracotomy.

Solid arthrodesis was demonstrated in all patients who underwent fusion procedures. Only one patient who developed kyphoscoliosis (Fig. 3d) at follow-up required surgical intervention. The patient, a 52-year-old driver with noncontiguous multilevel spinal injuries, presented a fracture dislocation C6-C7 (Fig. 3a, 3b) with tetraplegia ASIA grade A. He underwent hemicorporectomy C7, discectomy, insertion of an autologous iliac crest graft and anterior fixation using Caspar plate (Fig. 3c). Concentration on this dramatic proximal injury diverted attention from a less obvious lower injury, fracture dislocation L1-L2 (Fig. 3e) diagnosed at day 45 post-injury. He required surgical intervention for his deformity (Fig. 3f).

The mean follow-up time was 49 months (range, 3-158 months). At final follow-up, using the modified Prolo scale we obtained excellent functional results in 81 patients (64.80%), good results in 4.8%, fair results in 8%, poor results in 9.6%, while 16 patients (12.80%) died. The clinical and radiographic outcomes were better in operated patients. Correction of kyphotic deformity was significantly superior in patients operated at more than one level, and increasing deformity occurred in patient treated non-surgically and at the non-operated level for patient operated at only one level.

![Figure 3a: Preoperative cervical CT.](image)

![Figure 3b: Sagittal T2-weighed MRI) scans showing fracture dislocation C6-C7 with overlapping of C7 at C5 level and severe spinal cord contusion.](image)

![Figure 3c: Postoperative CT scan showing C5-C7 anterior fixation with Caspar plate.](image)

![Figure 3d: Posttraumatic kyphosis diagnosed at day 45 post-injury.](image)
Figure 3e: Lumbar CT scan revealing fracture dislocation L1-L2.

Figure 3f: Anteroposterior and lateral view radiographs showing well-maintained correction of the spinal deformity with posterior fixation using universal spine system T12/L1-L3/L4.

Discussion

The incidence of multilevel fractures and/or dislocations of the spine are not as low as commonly believed [11]. However, the relevant bibliography is scanty. Griffiths, Gleave and Taylor (1966) and Bentley and McSweeney (1968) each reported four cases [3, 4]. Kewalramani and Taylor (1976) reported an incidence of 4.2% for multiple noncontiguous injuries of the spine [9]. Calloff et al (1978) identified 30 patients (an incidence of 4.5%) with multilevel injuries among 710 cases [7]. Korres et al (1981) reported 18 patients (7.8% of those with spinal injury) who had multilevel injuries [2]. Gupta et al in 1989 found 91 patients (9.7%) with multilevel spinal injuries among 935 patients [1]. The 11.45% incidence of multilevel injury was greater than that reported previously. The higher incidence of multilevel spinal injuries documented in our patient population may be due to the fact that our hospital is a major trauma center for the state, and thus, an unusually high number of patients with multiple, severe injuries are flown in for treatment.

The primary lesion is the major vertebral fracture and/or dislocation that are easily recognized clinically or radiologically. But an associated secondary or tertiary fracture might pose a diagnostic challenge in some situations. This diagnostic dilemma is more pronounced when the symptomatic lesion is proximal to the secondary and tertiary fracture. Diagnosis of a secondary fracture may be delayed as long as 2.8 to 52.6 days in the literature [7, 12, and 13]. Ouzel and Bombard each reported a case where the diagnosis of secondary lesion was raised on the 55th day and 6th month post-injury respectively [14, 15]. In this study, the diagnosis of secondary or tertiary lesions was delayed of 1-140 days (mean, 5.9 days). Delays in diagnosis of such lesions have been explained by focusing on a particular lesion indicated by neurological signs and the inability to evaluate advanced radiological imaging tests in emergency. To avoid the risk of overlooking a second fracture and/or dislocation, fuller clinical examination and radiographic assessment of the cervical, thoracic and lumbar spine in patients with multiple injuries must be taken. Advanced imaging modalities (CT and MRI) are important for diagnosis and proper management plan [16].

The typical patient was a male in the third decade, as in previously reported series [4, 7, and 13]. In our series, 74.4% were males. The age range was 11 months-70 years (mean 34.57). Seventy-six patients (60.8%) were aged between 18-39 years (young adults). In our context, the high
male prevalence is explained by more hazardous socio-economic activities in men than in women. These are masonry, manual water well drilling, mounting electrical poles, combat sport (wrestling), harvesting fruits and leaves for livestock.

MVC and occupational injuries (falls) account for a substantial portion of multilevel spine injuries [10, 11, 17]. In our study, various factors incriminated for traffic collision were the poor quality of old-fashioned roads, non-compliance with traffic safety measures and sometimes young men's risk-taking with motor vehicles. Of the 63 cases involving MVC, 49 patients (77%) were unrestrained at the time of the accident. Falls from either tree used in feeding livestock or fruit trees were a particularity in our context. Of the 49 cases involving fall from height, 24 patients (49.2%) had fallen from trees. The correlation between the cause of injury and the number of injured vertebrae was strong (r=0.97). The reported high number of injured vertebrae was 12 and the cause was MVC [18]. We reported the highest number of injured vertebrae. A pedestrian struck by train (railway accident) and a worker in a gas cylinder manufacturing plant projected by gas cylinder explosion sustained injuries to 17 and 18 vertebrae respectively.

Multilevel spinal trauma frequently is associated with concomitant systemic injuries including head, in- tra-abdominal, thoracic injuries and long-bone fractures [6, 11, 19, and 20]. Unlike previous reports, in the present study, head and facial injuries were the least common associated injuries because patients with these injuries were respectively managed in neurosurgery and maxillofacial departments. Most of our patients (49.2%) who were injured in a fall from height were known to have been involved in fall from trees with primary impact on foot soles and secondary hand palms, which may explain the high number of associated calcaneal (22.45%) and distal radius (14.29%) fractures.

In our study, life support was the most important. A total of 17 patients (13.6%) with head, chest, abdomen injury and limb open fractures were treated surgically immediately after admission. Initial management mainly involved immobilization of the spine with orthosis or cast, skull traction and methylprednisolone was administered according to the results of the second National Acute Spinal Cord Injury Study (NASCi-2) [21]. Treatment option was dependent of certain factors, such as neurological deficit, spine instability and deformity and the number of intact spinal units between the two fractures and/or dislocations. All patients presenting stable injuries without neurological deficit were treated conservatively. All unstable levels of injury were treated surgically. Forty-four patients (35.2%) were treated conservatively and 81 surgically (64.8%).

**Conclusion**

High energy trauma is likely to be responsible for multilevel spinal injuries. Thorough clinical examination and conventional cervical, thoracic and lumbar radiographs are key for earlier recognition and better management of these injuries. If the presence of a fracture and/or dislocation is uncertain CT scans are required or if a patient had a spinal cord injury, magnetic resonance imaging is mandatory. Life support principles guide initial management. Stable levels of injury are treated conservatively while all unstable levels must be fixed surgically. The functional outcomes depend on initial neurological status and proper management.

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**Potential Conflicts of Interest**

The authors have no conflicts of interest relevant to this article to disclose.

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